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Synthesis, Preparation, Characterization and Fabrication of CdTe Thin film Solar Cells Using Vacuum Evaporation Technique

S. Sakthivel and V. Baskaran

Thin film Physics and Nano Science Laboratory,
PG and Research Department of Physics,
Rajah Serfoji Govt., College (Autonomous),
Thanjavur, Tamilnadu, INDIA.
email: sakthivel.sunmugam@yahoo,com; bass.physikz@yahoo.com

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ABSTRACT

An efficient Cadmium telluride (CdTe) thin film solar cell is prepared by vacuum evaporation technique on glass substrate. Cadmium telluride (CdTe) has small area and large efficiency for coming days and long been recognized as a promising material for thin film solar cell applications. Existing suitable material for solar cell production is the p-CdTe/n-CdS/TCO/glass structure. A $CdCl_2$ treatment homogenizes the distribution of acceptor-like defects or impurities leading to an optimized p-conversion of the CdTe layer. X-ray diffractometry (XRD) were taken for measuring the crystallite size, d-spacing value and structure of the CdTe film. The structural analysis showed that increase with thickness, crystallinity and grain size increases where as strain and dislocation density decreases. Surface morphology and defects were studied by scanning electron microscopy (SEM). UV-VIS absorption studies revealed that CdTe thin film has an optical band gap is optimal for photovoltaic applications. The photovoltaic properties including I-V characteristics, short-circuit current (I_{SC}), open circuit voltage (V_{OC}), Fill Factor (FF) and efficiency of CdTe films have been examined after fabrication.

Keywords: Cadmium telluride, CdS, optical band gap, photovoltaic properties.

1. INTRODUCTION

Now days, Cadmium telluride (CdTe) has a vital role on small area and high efficiency for thin film solar cell applications. Cadmium telluride (CdTe) have attracted significant attention as it is one of the first known thin film solar cell semiconducting material with a band gap of 1.49 eV. This makes it a promising material for the conversion of solar energy into electrical energy[1-2]. CdTe can be prepared by many techniques such as, SILAR method, spray pyrolysis, r.f. magnetron sputtering, reactive evaporation, sol-gel method, Electrodeposition, chemical vapor deposition, plasma evaporation, and chemical deposition methods[3-8]. The physical properties of the obtained films seem to be very sensitive to the detailed arrangement of Cd and Te atoms, which in turn is influenced by the deposition method and the particular conditions.

In this work, we produced CdTe thin film solar cell on the glass substrates using vacuum evaporation technique and then annealed the CdTe films at 400°C treated with and without $CdCl_2$. Effects of growth and post-deposition annealing on the film properties such as stabilization of crystal structure, grain size, texture, and optical band gap were studied to see if there was any correlation between these parameters.

2. EXPERIMENTAL DETAILS

CdTe metal powder has been synthesized using high purity cadmium and tellurium elements are placed in a quartz ampoule. The sealed ampoule is placed in a furnace and then gradually heated in steps up to 1400K. The ampoule is maintained at this temperature for about three hours and then allowed to cool slowly to room temperature. Finally the Preparation of CdTe film was done by thermal evaporation. The chamber pressure was maintained at 10^{-5} to10^{-6} mbar during evaporation. These films were annealed before and after $CdCl_2$ treatment at 400 °C for 30 min. The $CdCl_2$ layer was deposited on CdTe film surface using a saturated solution of $CdCl_2$ in boiling methanol for 5 min. After the application of the solution on the film surfaces, the films were heated at 400 ◦C for 30 min in air. To form p-n junction with the p-type CdTe, n-type CdS thin film is deposited on the absorber layer by vacuum evaporation method. The surface of CdTe thin film is to be fully covered by CdS thin film, leading to shortage between front contact and back contact. To prevent leakage intrinsic ZnO (i-ZnO) thin film is coated on CdS before transparent conducting oxide (TCO) thin film is deposited as the front contact layer of the cell.

The structural properties were determined by X-ray diffraction (XRD; Shimadzu) with Cu (Kα) radiation (λ = 1.5406 Å). Film morphology was analyzed by scanning electron microscope (SEM).The optical absorption and transmission spectra were obtained using a UV-vis spectrophotometer within the wavelength range of 300nm to 1100 nm.

3 RESULTS AND DISCUSSION

3.1 X-Ray diffraction (XRD)

X-ray diffraction patterns of the CdTe film were recorded on Model Rigaku X-ray diffractometer with scanning angles in the range 10 – 90 degree using CuK_{α} radiation (λ=1.5406 Å). Fig.1 shows X-ray diffraction pattern of as-deposited CdTe thin film on glass substrate by thermal evaporation method. In the present diffraction pattern of XRD, dominant peaks at 23.39^{o}, 39.34^{0}, 47.46^{0}and 66.70^{o} corresponding to the (111), (220), (311) and (331) planes of CdTe are seen with cubic crystal structure.

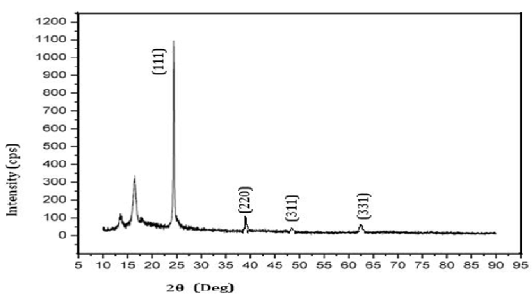

Fig.1 XRD pattern spectrum of the CdTe film

An average value of the crystallite size at the (111) plane can be obtained by applying the Debye-Scherer's equation and strain, dislocation density calculating and reported[9-12].

$$D = 0.9\ \lambda/\beta\cos\theta \qquad (1)$$

Where, λ=1.5406 Å for CuKα, β is the full width at half maximum (FWHM) of the peak and θ is the diffraction (or) Bragg's angle. The sample as-deposited CdTe resulted in an average crystallite size of approximately 13 nm.

3.2 Optical Properties

In order to investigate the optical properties of thin film solar cell at various ratios of p-CdTe/n-CdS, the transmittance was measured as a function of wavelength in the range of 300-700 nm. All the films showed the transmittance higher than 80% in the visible region. The optical absorption coefficient (α) was calculated from equation:

$$\alpha = (1/t)\ \ln\left[(1-R)/T\right] \qquad (2)$$

Where t is thickness of thin film, T is transmittance and R is Reflectance. The fundamental absorption, which corresponds to the transition from valence band to conduction band, can be used to determine the optical band gap (Eg) by the equation below:

$$\alpha\, h\, \nu = A\, (h\nu - Eg)^{\,n} \qquad (3)$$

Where $n = 0.5$ for direct transition, $n = 2$ for indirect transition, A is constant, h is Planck's constant (6.62x10-34 J.s) and ν is frequency of incident photon and E_g is 1.47ev achieved.

3.3 Morphological analysis Scanning Electron Microscopy (SEM)

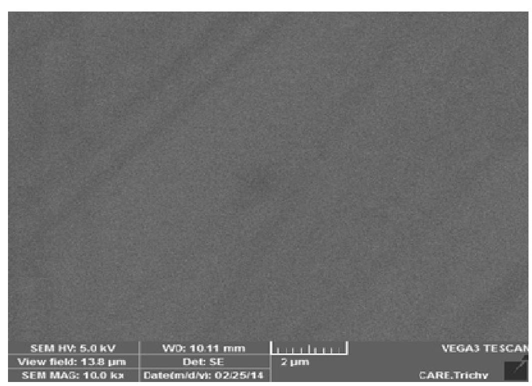

Figure 2: The SEM image of the CdTe thin film -2 µm

The surface morphology was studied by scanning electron microscopy (SEM).The microstructure SEM image of the p-CdTe thin film on amorphous glass substrate is as shown in figure 2. The as-deposited film shows uniform surface morphology for p-CdTe on glass substrate. Nanometer size spherical grains (75-190 nm) are observed. These bigger size grains are formed due to agglomeration of small size nanoparticles since the particle size estimated by structural studies is 12 nm.

4. CHARACTERIZATION OF THE CELL

For the spray deposited CdSe material, the power conversion efficiency (η) of the device was relatively 5.27%, since the data of photovoltaic parameters such as Jsc, Voc, and FF were obtained.

5. CONCLUSIONS

In this study, we have found that the band gap of CdTe thin film is 1.47eV which is tunable via varying the thickness of the film. The thickness of the film strongly affects the performance of CdTe solar cells. We have found that 74.92 nm thickness of Cu_2S film is optimum for solar cell performance. Nanometer size spherical grains (75-190 nm) are observed. These bigger size grains are formed due to agglomeration of small size nanoparticles since the particle size estimated by structural studies is 12 nm. In the present diffraction pattern of XRD, dominant peaks at 23.39^o, 39.34^0, 47.46^{0}and 66.70^o corresponding to the (111), (220), (311) and (331) planes of CdTe are seen with cubic crystal structure. These films were allowed to $CdCl_2$ treatment, the sample is transformed into a mixture of hexagonal and cubic phases; the hexagonal phase being predominant phase. The grain size increased for the CdCl2 annealed film. Through using Cu_2S as back contact buffer, the energy conversion efficiency in our samples of CdTe solar cell can reach up to 5.27%.

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